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16. Abstract

Stimuli of varying strength, frequency and duration were applied to the anterior cingulate gyrus in unanesthetized cats with freedom of movement.

The motor, vegetative and electrical effects of these stimuli, although inconstant, lead to a consideration of the role of this structure in the extapyramidal control of motricity.

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THE EFFECTS OF STIMULATION OF THE ANTERIOR CINGULATE GYRUS IN CATS WITH FREEDOM OF MOVEMENT

G. Dapres, J. Cadilhac and P. Passouant

The motor and autonomous responses after stimulation of the /654* anterior cingulate gyrus have often been described. But there are many divergences between the various authors concerning the importance, typography and duration of these responses. Side by side with inhibiting effects, with arrest reaction and hypotonia (1,2,3), various movements have been obtained by Sloan and Kaada (4), Showers and Crosby (5), on acute preparations, and by Hughes (6) in the /658 chronic animal.

During this work, we have researched the effects of stimulation of the anterior cingulate gyrus on movements and emotional expression, vegetative effects and post-discharges which such stimulation causes in the unanaesthetized animal with freedom of movement.

Materials and Methods

In 26 adult cats, bipolar electrodes composed of two stainless steel 0.12 mm wires insulated with teflon were placed stereotaxically in the same restricted area of the anterior cingulate gyrus near the joint of the corpus callosum. Simultaneously, stimulating and recording electrodes were placed in various cortical structures (octosylvian and suprasylvian cortex) and subcortical structures (anterio-ventral node of the thalamus, caudate node, hypothalamus and mesencephalic reticulum).

The animals were studied for several weeks after the operation and the position of the electrodes was carefully verified each time after the sacrifice of the animal.

*Numbers in margin indicate pagination in foreign text.

Stimuli were delivered in the form of series of brief shocks (1 msec) at varied frequencies (30 to 300 cycles/sec) and voltages (3 to 10 volts).

Results

1. The motor effects are independent of the frequency of the stimulus and are of two types: arrest reactions and postural changes with movements.

a) The arrest reaction is obtained with a threshold voltage (of 6 to 8 volts); the animal stops its current movements: it stops walking or eating; if standing, it collapses and leans towards the stimulated side.

b) The posture modifications and movements appear with higher voltages (8 to 10 volts) and involve the head, the hindquarters or the forequarters.

[illegible] The head is inclined controlaterally, the movement of the eyes procedes and follows the rotation of the head. Secondarily, there appears a droop of the homolateral ear, closing of the homolateral eye, and shaking of the head.

The effects on the forequarters are the following: the animal carries the homolateral foreleg extended and abducted, and the tail is, at the same time, carried to the side. Secondarily are produced "pedaling movements" of this dominant leg, affecting the proximal portion, while the distal portion dangles in hypotonia. These rythmic movements are accentuated if the stimulus is prolonged. Subsequently, when the animal moves about, it does so on three legs, with the homolateral foreleg flexed, not touching the ground, the hind legs remain bent and the animal slides on its hindquarters.

The effects on the posterior quarters are the following: elevation of the hindquarters of the stimulated animal with a controlateral

swaying possibly translating sexual behavior; the homolateral hind leg is flexed and raised, not touching the ground. The claws are extended and, when the animal moves about, this leg remains partially flexed. The hind leg may be affected by "pedalling movements" of strength and frequency proportional to the duration of the stimulus. /639

The motor effects generally cease at the end of the stimulus, or rarely persist more than a few seconds. It is only with the higher voltages that crises are produced with homolateral falling of the animal, followed by clonus of the hindquarters, then of the forequarters.

2. The vegetative effects: bilateral mydriasis has consistently been observed, salivation more rarely. The respiratory modifications are inconsistent. Most often they consist of apnea on exhalation lasting the duration of the stimulus and appear with relatively weak stimuli. In contrast, for higher voltages, there has been noted a tachypnea with panting. Similarly bradycardia is obtained with stimuli near the threshold, and tachycardia for stronger stimuli.

3. The electrical effects appear inconsistently for low-voltage stimuli (2 to 8 volts). These post-discharges may be ipsilateral or bilateral.

a) Ipsilateral post-discharge. This response is inconsistent. When it appears it takes the form of post-discharge localized in the stimulated region and elicited by low voltage stimuli (2 to 4 volts). It consists of waves with positive peaks, of stable frequency (7 to 8 cycles/sec) and an amplitude of 40 to 60 microvolts. They are of long duration of between 20 and 30 seconds and sometimes more. On top of this local discharge appear bilateral sleep bursts which interfere with, without modifying, it.

b) Bilateral post-discharge. This response is rarer than

ipsilateral post-discharge. It appears in an inconsistent manner with low voltages. It takes the form of a rapid spindle (12 to 15 cycles/sec) of low amplitude, usually of short duration (10 to 15 sec). It involves the two anterior cingulate gyri as well as the posterior cingulate gyrus.

Discussion

The motor effects obtained under our experimental conditions by stimulation of the anterior cingulate gyrus have, in spite of their inconsistency and variability, certain common points. They correspond to an arrest reaction, a posture modification and interesting movements of the homolateral limbs. The arrest reaction, sometimes followed by a slow collapse of the animal, are the only inhibitor effects which we obtained. They are less general than those obtained by Bailey (1), Smith (2) or Ward (3). On the other hand, we observed a pedaling movement which had only been reported after stimulation of the extrapyramidal structures of of the cerebellum (7).

The interpretation of these motor effects is a delicate matter. The diffusion of the stimulus to neighboring motor areas, in particular to the supplementary motor area, which was envisaged by Messimay (8), does not seem to be acceptable. Showers (9) showed that the same effects are obtained following disconnection of the cingulate gyrus from the frontal areas. On the other hand, these movements may be linked to sub-cortical cingulate efferences. The anatomical relationships between the thalamic nodes (10), the striated bodies, and the tegmentum, are significant (9). The relationships with the thalamic reticulate formation and the cerebral trunk have been considered by Sloan and Jasper (11). It is possible that, particularly in the case of the rythmic movements of the limbs, the functional relationships between the cingular gyrus and the cerebellum are brought into play as suggested by the experiments of Robinson and Lennox (12) and especially the analogy between the movements obtained by the stimulation of the anterior cingulate gyrus and the stimulation of the cerebellar vermis (7).

A somatotopy of the motor responses has been described at the level of the cingulate gyrus of the Monkey and the Cat (6,9). But our results demonstrate that this somatotopy is merely preferential, as it is possible to elicit, from the same point of stimulation, either localized responses of the fore or hind limbs, or more general responses, according to the initial posture of the animal and depending on the strength of the stimulus.

Finally, the vegetative effects obtained from the anterior cingulate gyrus are in no way specific, since they are found at numerous other limbic regions. The post-discharges, which seem to be independent of the motor reaction, habitually remain localized in the stimulated part or are sometimes transmitted controlaterally, but we have not demonstrated, through electrical stimulation, any generalized, immediate discharge, in contrast to what is seen after the creation of a chronic epileptogenous seat.

Summary and Conclusion

The motor, vegetative and electrical effects of the stimulation of the cingulate anterior gyrus, in the nonanaesthetized cat with freedom of movement, make it possible to consider the role of this structure in the extrapyramidal control of motor activities, bringing into play the various telencephalic structures and the cerebellar systems.

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